

Pettenkofer Revisited

The Life and Contributions of Max von Pettenkofer (1818-1901)¹

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If the name of Max von Pettenkofer is remembered at all in America it is probably because he drank live cholera vibrio in apparent defiance of the germ theory and did not fall ill. Yet this act was not a hasty, emotional one but one of strong conviction that more than just the organism is needed to cause disease. It was a beginning of the epidemiologic concept of multiple causation. Pettenkofer was an able and prolific worker who made notable contributions to epidemiology, environmental health, preventive medicine, chemistry, and physiology. One time actor and sometime poet, his memory is revered in his native city of Munich where there is an important street that bears his name on which the Max von Pettenkofer Institute for Hygiene and Medical Microbiology stands. A statue of Pettenkofer is located on Maximilian Strasse in the center of the city. In 1965 the 100th anniversary of the establishment of the first Department of Hygiene was celebrated. Only three short biographies of this impressive man have been published (1-3), one of which is English and appeared in 1927. This paper is to call attention of English readers again to Pettenkofer and to his varied contributions.

LIFE

Max von Pettenkofer was born December 3, 1818 in the small town of Lichtenheim near Neuberg on the Danube (Fig. 1). While the house in which he was born appeared to be a comfortable one, it was not large enough for the eight Pettenkofer children so that poor Max had to sleep in the hallway at the top of the stairs (2) (Fig. 2). There is little in the family history to predict the success Pettenkofer would later achieve. His father was a small landworker but not actually a farmer. The family was poor and there was not enough to go around. As fifth in the family Max led an unhappy early childhood until at the age of 9 he was sent to Munich to be taken in by his uncle, Dr. Franz X. Pettenkofer (1783-1850)

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FIG. 1. Pettenkofer's birthplace in Lichtenheim, near Neuberg on the Danube.



FIG. 2. As fifth of eight children Max had to sleep in this corner at the top of the stairs.

who through his services in the Napoleon's Russian military campaign of 1812 had gained recognition and had been appointed as court apothecary. Young Max studied in the grammar or Volksschule, then in a Latin school, and afterward in the high school or Gymnasium from which he graduated with distinction in 1837, age 18. His early interest was in philology and he began to write poetry and sonnets. A collection of these was later published (5). He entered the University of Munich but switched from philology to chemistry, studying as an apprentice in the Kgl. Hofapotheke. But he was not interested at this point in chemistry, nor in law, nor in theology (2). Rather he became involved in acting as he had enjoyed playing a role in the theater in his youth. He became embroiled in an argument with his uncle over his career who then presumably boxed him on his ear (4). Max left his uncle and entered the theater. In 1840 he was playing under the stage name of Tenkof in the theaters of Regensburg and Augsburg (Fig. 3). Despite his good looks and enthusiasm for the theater and for literature, he received only reserved criticism in the newspaper (3). Another biographer, however, says he received favorable press comment (1). At this time he met his cousin, Helene Pettenkofer, in nearby Friedberg (Fig. 4). She was an attractive and convincing young lady whom he later married and who effected a reconciliation with his uncle. So he returned to Munich in 1841 to begin medical studies with a strong emphasis on chemistry. His first publications in 1842 at age 24 were on a method for the detection of arsenic with the Marsh apparatus and on the separation of arsenic from antimony. In 1843 he received two degrees—that of apothecary in March, and a few months later that of Doctor of Medicine, Surgery, and Obstetrics. His medical thesis was on a South American plant, *Mikania Gauco*. After

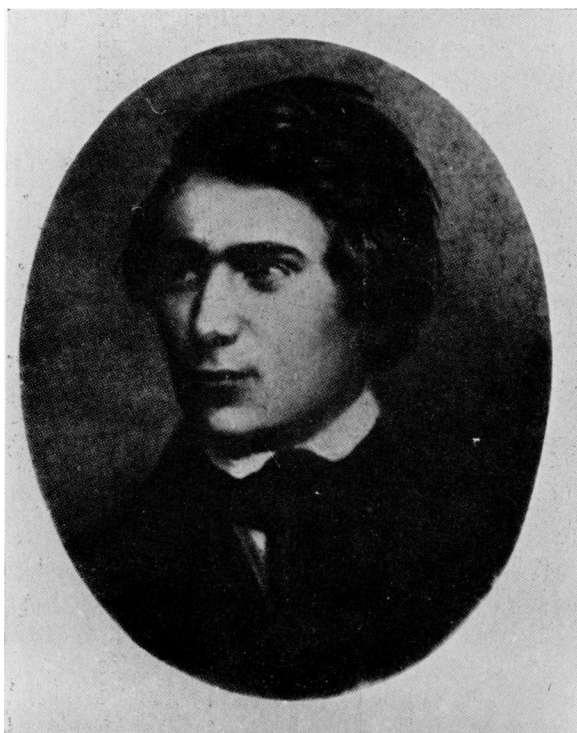


FIG. 3. As "Tenkof" Pettenkofer acted in the theatre.



FIG. 4. Helene Pettenkofer, his cousin, whom he later married.

graduation Pettenkofer went first to Würzburg where he did chemical research on different substances in the urine, then in 1844 he was able to move to the University of Giessen to work under the renowned chemist, Justus von Liebig. Liebig was a great teacher and had much influence over Pettenkofer. As no professorship was open in Giessen, Pettenkofer took a job in the mint where he made several contributions to the improvement of coins and preservation of valuable metals. In 1846 he was made an associate of the Academy of Sciences. In 1847 a professorship in medical chemistry was created at the University of Munich to which he was appointed at the yearly salary of \$280 plus 2 measures of wheat and 7 measures of rye. He was provided rooms for his research in the University. His first pupil was Carl von Voit who later did much work with him in physiology and metabolism. In Pettenkofer's series of lectures as Professor of Chemistry the titles changed from year to year: first they were on physical chemistry and diet, then on diet and public health, and then increasingly on sanitation, public health, and on hygiene. The title "Lectures on Hygiene" was first used in 1865 and retained thereafter. After the death of Pettenkofer's uncle in 1850 he was appointed court apothecary. This enhanced his income and provided residence in the house in which he was brought up with his uncle. During this period and at the insistence of King Max he talked his old professor, Liebig, into coming to Munich. Pettenkofer was given a suite of four rooms in the new Institute of Physiology built in 1855. In the years 1864–1865 he was appointed Rector of the University of Munich, and because of his interest in hygiene influenced King Ludwig II to establish a chair in this subject in all three Bavarian Universities. Pettenkofer himself was made first Professor of Hygiene in Munich (Fig. 5). Starting about 1851 his interests turned to cholera, its epidemiology, and its transmission in ground soil. His travels carried him widely in epidemiologic and ecologic investigations in the field

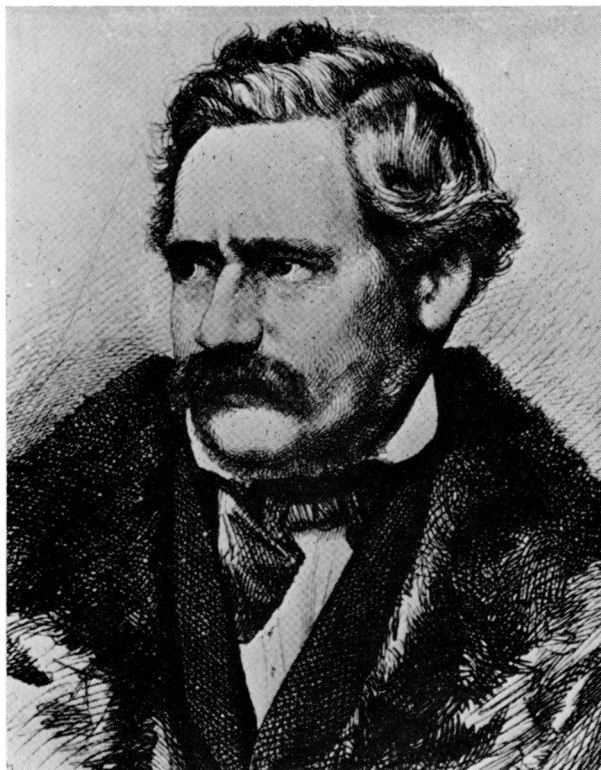


FIG. 5. Pettenkofer in his prime.

of public health and sanitation. He was asked to come to the University of Vienna in 1872 as Chief of a new Hygiene Institute. Much like today's professor, Pettenkofer used this offer as a wedge at home. He agreed to stay at the University of Munich if they would build him a similar institute. The Bavarian government agreed to this. It opened in 1879. He also became active in improving the health of the city of Munich and in 1893, 50 years after receiving his doctorate, he was awarded the Gold Burgess Medal, the highest honor the city could bestow. He was given personal nobility, the Harben Medal of the British Institute of Public Health, and in 1890 became president of the Bavarian Academy of Sciences (Fig. 6). On his 70th birthday his pupils presented him a marble bust and the city of Munich gave 10,000 marks and the city of Leipzig 5,000 marks to support a Pettenkofer Foundation for Hygienic Investigation.

As a man, Pettenkofer was said to be one of deep feeling, of warmth, of humor, and sometimes of melancholy. Through his interest in the theater and literature he became friends with many artists of his time. His wife, Helene, died in 1890. He had five children, three of whom died early of tuberculosis, as had his own mother. Pettenkofer turned increasingly to writing (Fig. 7). In 1894 he gave up teaching, 2 years later he resigned as court apothecary, and in 1899 stepped down as President of the Academy. He spent much time in his summer place at Lake Starnberger, rowing on the lake or walking in the forest. Early in 1901 he had a bad throat infection which caused pain and a depression. He had already said of suicide that it is "no heroic death, and only to be condoned when it is for the benefit of loved ones or when done by one irresponsible. In such case it is a tragedy."

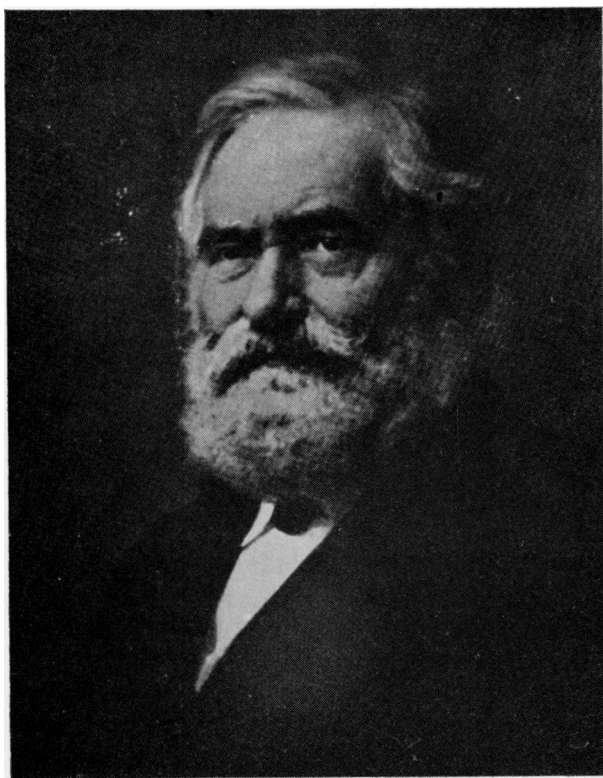


FIG. 6. Pettenkofer in later years.

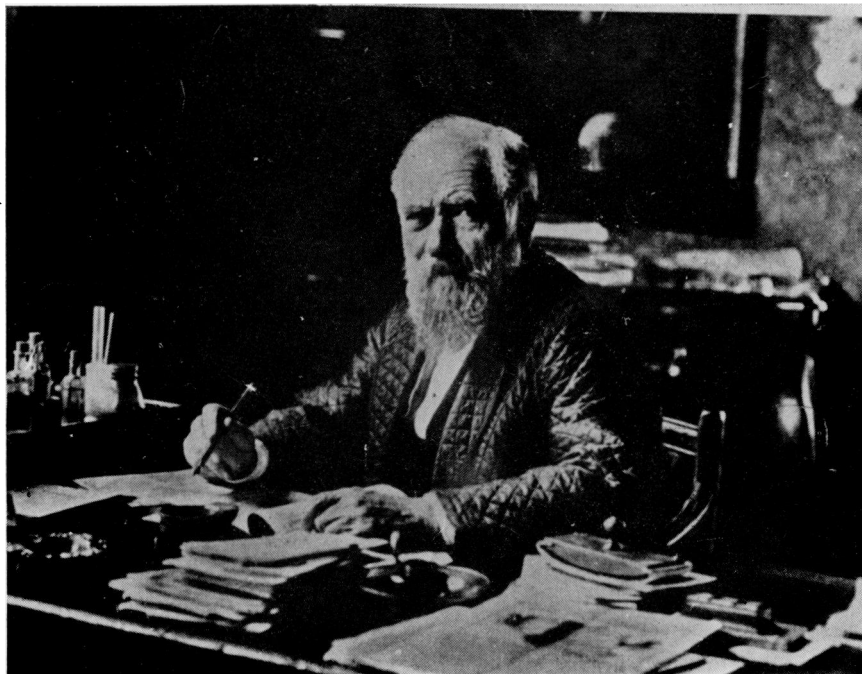


FIG. 7. After retirement he continued to write.

(Ref. 1, p. 44). He apparently thought it was justified in his own case. He killed himself with a revolver February 10, 1901, at the age of 82. At autopsy advanced chronic meningitis was found and cerebral calcification. He is buried without a headstone in a simple grave in Thalkirchner cemetery in Munich. His grave is easily overlooked but his memory continues on in many ways in the hearts and eyes of the people of Munich. His statue is located on Maximilianplatz across from that of his old teacher Justus Liebig. Off of Sendlinger Tor Platz is a street that bears his name with the newly rebuilt Max von Pettenkofer Institute.

CONTRIBUTIONS TO CHEMISTRY AND PHYSIOLOGY

Pettenkofer's early training, interests, and professional life centered about chemistry. Beginning in medical school, he contributed to a varied group of chemical fields. By age 33 he had attained a wide reputation as a chemist and at 37 he became a professor of chemistry. Some of his work in this field is listed in Table 1.

In medical chemistry he demonstrated hippuric acid, sulphocyanic acid, and a nitrogenous product, later shown to be creatinine and creatine in the urine. He worked out a test for bile still in use and a copper amalgam for filling teeth. With Liebig he developed a method for preparing a meat extract used for making soup. This was produced in large quantities from beef in South America where a plant was established with the name "Liebig's Meat Extract Company."

Pettenkofer published about 20 papers in industrial chemistry. He contributed to the improvement of coins and valuable metals and the manufacture of a good German cement. He worked out a method for producing illuminating gas from wood with which the city of Basel and Munich's drama theater and the main station were illuminated. The procedure was used widely in Europe until the decreasing supply of wood made its production too expensive. However, his interest in lighting continued through the years: in 1890 he published a paper on gas lighting during anaesthesia with chloroform gas.

In the field of art chemistry he made an important contribution. Increasing damage to the oil paintings in the art galleries of Munich was occurring. Pettenkofer was appointed as a member of a commission to investigate it. The paintings were found to become unclear due to the formation of a mildew or mold on the surface so that the varnish became opaque. He traced the problem to the oils used for dissolving the pigments; these became hard and less translucent with time due to conden-

TABLE 1
SOME CONTRIBUTIONS TO CHEMISTRY

1844	Demonstration of hippuric acid in urine Creatinine in urine Test for bile
1848	Copper amalgam for teeth
1848-49	Improved methods for gold and silver assay Improved methods of making coins
1849	Production of good German cement
1851	Water analysis at Heilbronn
1854	Measure of zinc content of air
1856	Synthetic substance for antique glass
1857	Illuminating gas from wood. Lighted city of Basel
1858	Method of CO ₂ measurement in air Production of Liebig's meat extract
1863	Method of restoring old paintings

sation of surface water and cracking. By applying hot alcohol vapor to the surface the varnish was reunited. Avoiding moist environments prevented reoccurrence. He also found a way of making a substance used in the preparation of antique glass (haematinon). In all, about 40 papers in chemistry bore Pettenkofer's name.

Pettenkofer also carried out important studies in physiology, metabolism, and nutrition over many years. Most of these were done with his associate Voit who carried on after Pettenkofer became increasingly involved with cholera studies. About 30 publications in physiology appeared. The most important work was in the field of respiration. A respiration chamber was constructed for \$2800 with a grant from King Max II: measured air was placed with the individual in the chamber and exhaled air, feces, urine, etc. were collected and examined. Experimental work on respiration, metabolism, and nutrition including research in dogs was made.

CONTRIBUTIONS TO HYGIENE

Pettenkofer was responsible for the establishment of the first three chairs of Hygiene in medical schools in Bavaria in 1864/65. Hygiene was made a required course in these schools and included in the medical examination; by 1883 hygiene was taught in other German medical schools and an examination was required throughout the German empire. A list of the subjects included by Pettenkofer is given in Table 2. Most teachers of preventive medicine and public health could get by with these same lecture topics 100 years later. He did not confine his lectures to medical students but felt a responsibility to educate the general public. He gave extensive public lectures on medical economics, urban health, and hygiene about 1870.

There were no journals in hygiene and bacteriology which he felt to be appropriate for publishing much of his work, so he established the *Zeitschrift für Biologie*

TABLE 2
TOPICS INCLUDED IN PETTENKOFER'S LECTURE ON HYGIENE^a

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1. Atmosphere
 2. Physical and chemical changes in the atmosphere; climate
 3. Clothing, skin care; care of body; exercise
 4. Retention of air, water, and heat in building materials
 5. Ventilation
 6. Heating
 7. Lighting
 8. Building sites and grounds
 9. Ground air and ground water
 10. Influence of soil on occurrence and spread of disease
 11. Drinking water; care of human habitations
 12. Food and its relationships
 13. Milk, meat, bread, vegetables, fruits, and other plant foods, alcoholic drinks, vinegar
 14. Nutrition and care of various classes of society under varied conditions
 15. Collection and disposal of feces and other refuse; sewage
 16. Disinfection
 17. Coronor and burial regulations
 18. Health in dangerous trades and factories
 19. Schools, barracks, nursing institutions, hospitals, prisons
 20. Poisons and their regulation
 21. Medical statistics and biostatistics
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^a Adapted from Ref. (1), pp. 35-37.

in 1865 and with his students the *Archiv für Hygiene* in 1883. He wrote a five-volume Handbook für Hygiene (1882) with Ziemssen. He also contributed to one on Hygiene and Occupational Health (1882). As no laboratory existed for his students in hygiene, he convinced the Bavarian government to build one for him or he would take a professorship in Vienna. The Hygienic Institute at the University of Munich was opened in 1879. Students came from all over the world to work there. On July 13, 1944, the institute was destroyed by bombs. It was not rebuilt until 1967 when it was reestablished as the "Max von Pettenkofer Institute for Hygiene and Medical Microbiology" at a location down the street on Pettenkofer Strasse from the original building. The current professor of Hygiene and Director of the Institute is Dr. Herman Eyer, the fifth incumbent of this position after Pettenkofer. In 1965 his institute celebrated the 100th anniversary of the Department of Hygiene in the University of Munich with the publication of a memorial pamphlet (4). In 1876 Pettenkofer was offered the job as Head of the German Empire Health Council but he turned it down to continue teaching. He became a consultant to it. He was also against intemperate use of alcohol, or indeed any use of it. In recognition of this the "Munich group against misuse of alcohol" erected the Pettenkofer Fountain in his honor in the building of the Academy of Medicine.

CONTRIBUTIONS TO ENVIRONMENTAL HEALTH

Pettenkofer's interest and research extended to almost all aspects of the environment: air, drinking and ground water, soil, sewage, river pollution, heating, clothing, and the urban environment. He established a clean water supply for the city of Thalkirchen as a model for other cities. He influenced the burgomaster of Munich and the city architect to design and provide a clean water supply from the mountains. A central abbatoir was built in 1878. With his pupil, R. Emmerich, he found that the Isar River water remained good even with sewer pipes in the ground; indeed, because of its swift flow and size, sewage could be safely discharged into it. In Munich, as a result of these measures, the general mortality fell as did the mortality from typhoid fever (Table 3). Munich became and has remained a healthy city. In 1873 he published one of his public lectures on "The value of health to a city" which was later translated into English by Henry E. Sigerist (6). A good biographic sketch is included. This work is an important contribution to medical economics. Pettenkofer said: "Everyone who lives upon the earth deserves to be well, for a life without health is a misery—a martyrdom from which everyone longs for release, and when it may not be by other means, even by death." He showed the monetary saving resulting from improved health, an early example of cost accounting for justification of health needs. For the city of

TABLE 3
EFFECT OF IMPROVED SANITATION ON MORTALITY IN MUNICH^a

General mortality	Deaths
1870	40 per 1,000
1890	30 per 1,000
Mortality from typhoid fever	
1880	72 per 100,000
1898	14 per 100,000

^a Derived from Ref. 4, p. 40.

Munich, then about 170,000 population, he estimated the sick days per year were 20 per person and the time lost from work cost 3,400,000 gulden. In London improved sanitation had resulted in a drop in the death rate from 42 per 1000 in 1681 to 22 in 1856. He said if Munich reached this level of sanitation 25,000,000 gulden would be saved each year. He helped to develop sewerage systems for Munich and other cities.

The 55 or so publications that can be classified as contributions to environmental health are too numerous to present here in detail. Among them were the recognition of zinc in the air, a method of measuring CO₂ in air, and the demonstration that air permeates soil—indeed a canary can survive between two layers of soil as he showed in elegant experiments. Air exchange in houses, heating by gas, steam, or oil; sewage disposal in Basel, Munich, Frankfurt; drinking water in Linz; ground water levels in relation to health and disease; these and other topics were subjects of his study and publications.

CONTRIBUTIONS TO EPIDEMIOLOGY

The main focus of Pettenkofer's investigations in epidemiology was on cholera. His studies on this topic numbered about 71 publications to 1894. Another subject of interest was typhoid fever with 12 publications.

Pettenkofer expressed the belief in 1869 that both cholera and typhoid fever were due to specific microorganisms elaborated in the patient and excreted into the environment. This was 14 years before cholera vibrio was first demonstrated by Koch (1883) and 12 years before typhoid bacillus was found by Eberth (1881). Unlike Koch he felt that more than just the organism alone was needed to produce disease. To have an epidemic he felt four criteria were needed: (1) a specific germ; (2) certain local conditions; (3) certain seasonal conditions; (4) certain individual conditions (Ref. 1, p. 45). A specific germ exists but alone cannot cause disease; person-to-person contagion was denied, even given individual susceptibility. The susceptibility and immunity of places and of certain periods of time must also be taken into account. He felt the condition of the soil to be the key to transmission, and that a factor in it contributed something (called "Y") to the development of the germ (called "X"). This Y factor occurred in moist, porous soil containing decaying organic matter. The final product, called Z, produced clinical cholera and propagated in the human intestine. The agent, or X, could not produce illness unless it developed in this way (i.e., acquired virulence) in the soil under certain defined conditions. These included a porous soil and a changing condition from a moist to a dry state. The organism could not mature in soil that was too wet, or too dry, or impervious to water. In addition, it must contain decaying organic material in which the germ could "ripen." The proper conditions were correlated with the level of ground water: as the level of ground water dropped and moisture decreased, epidemics occurred. This was Pettenkofer's "Boden theory" or soil theory of the transmission of cholera. He presented it repeatedly in voluminous papers over almost 40 years, often with changing emphasis, and with selected examples favorable to the concept. It occupied an important place on the stage in the controversy between the "contagionists" and "miasmiasts" in this period. Pettenkofer's exposition of this view included seven papers in the *Lancet* in 1884 (7), several other articles in English (8–13), and a ponderous series in German occupying 756 pages of the *Archiv für Hygiene* in 1886–1887 (14). His pupils carried on his philosophy in six commemorative volumes in the

early 1900's. One of these, by Emmerich (15) is 748 pages in length and brought in more recent bacteriological and chemical evidence in support of the theory. In his excellent biography Hume (1) dealt at great length with the "Boden theory." In an outstanding analysis entitled "Pettenkofer—the last stand" C. E. A. Winslow evaluated his views and their impact on epidemiology (16). Even in 1973 the "Boden theory" still casts its shadow (17). Pettenkofer's concept of seasonal occurrence, of the susceptibility of places to epidemics, and his approach to prevention were all viewed in relation to the soil-transmission thesis. He had little faith in the value of disinfection or of isolation of patients in the control of cholera.

Whatever shortcomings in Pettenkofer's logic may have existed, an unwillingness to investigate personally was not one of them. Wherever cholera occurred in presumably rocky soil, which Pettenkofer felt should not happen, he went to study it in person. He was a field epidemiologist. He traveled to Krain in the Mountains of Croatia to make a study of the soil in six villages, finding a high-grade porosity wherever cholera existed. In 1868 he made similar trips to Gibraltar and to Malta.

Pettenkofer was so convinced that the organism alone was insufficient to cause illness that he resolved to carry out the "experimentum crucis" on his own person. This famous event occurred on October 7, 1892 when he was 74 years old. He obtained a fresh culture of cholera vibrio isolated by Prof. Gaffky from a patient dying of cholera. A transfer was made into bouillon and he swallowed 1.0 cc on an empty stomach after neutralizing the acidity with sodium bicarbonate. No symptoms developed except a "light diarrhea with an enormous proliferation of the bacilli in the stool." Of this experiment Pettenkofer wrote:

"Even if I had deceived myself and the experiment endangered my life, I would have looked Death quietly in the eye for mine would have been no foolish or cowardly suicide; I would have died in the service of science like a soldier on the field of honor. Health and life are, as I have so often said, very great earthly goods but not the highest for man. Man, if he will rise above the animals, must sacrifice both life and health for the higher ideals." (from Ref. 1)

I am told by Prof. Eyer, current Professor of Hygiene at Munich, that Pettenkofer undoubtedly had had cholera himself during the epidemic of 1830, so that little immunity probably persisted. (Personal communication at Munich, Aug. 1972). Several of Pettenkofer's students followed their master's example. Two of them were not as lucky (or as immune) so that a severe "cholera" developed but there were no deaths. These experiments showed that clinical cholera was certainly not an inevitable consequence of ingesting virulent cholera bacillus.

Pettenkofer's views were at variance to those of the Englishman John Snow and his German countryman, Robert Koch. His argument with Snow primarily concerned the drinking water concept. John Snow was an anaesthetist whose hypothesis of the spread of cholera was first published in 1849 (18), elaborated in papers in 1851 (19), 1853 (20), 1854(21–23), and finally culminated in a major book representing a second edition of his 1849 work (18) containing all his theories which were published in 1855 (24, 25). Two important bases for his drinking water theory rested on (1) the lower frequency of cholera deaths in London in water supplied by the Lambeth Company originating in the Thames above the polluted part (37 deaths/10,000 houses) as compared to the high death rate of 315/10,000 houses in water from the Southwark and Vauxhall Company which was obtained from an impure source lower down on the Thames; (2) the analysis

of the Board street pump outbreak in which he traced the spread of cholera to well water. Pettenkofer's interest in cholera began about 1851. As a member of the Commission on Cholera he analyzed the 1854 outbreaks in Munich and nine other German cities in great detail. I have had the opportunity of examining an original copy of the impressive book of 371 pages which Pettenkofer published in 1855 on the spread of cholera in these areas (26). It is clear he was aware of Snow's important observations and said that no one in his right mind can neglect them. However, he felt that more popular than scientific opinion favored this concept, but was determined to evaluate it himself. In Munich he noted the possible spread from the polluted water of the Isar river which may have contaminated low-lying wells but felt that the spot map of cases by rates of illness did not support this, nor did his analysis of areas supplied by two water sources (federal and state). While he could not implicate drinking water as the source of cholera he was well aware of its potential in this regard. In the summary of the book he warned against taking drinking water from polluted rivers even though it is filtered. He urged avoidance of fecally contaminated water. From his first interest in drinking water theory in 1855 he became increasingly convinced that it did not play a major role itself in the spread of cholera. Despite this he was an advocate of the need for pure water but felt the cholera organism must first go through soil contaminated from fecal discharges of cholera patients. Pettenkofer's evaluation of Snow's observations on different attack rates in the two London companies were given in his 1884 review in these words (p. 863 Ref. 7):

"For good health, pure water is as necessary as pure air, good food, comfortable quarters, and so forth. I myself am an enthusiast in the matter of drinking water, but not from fear of cholera or typhoid fever, but simply from a pure love for the good. For me water is not only a necessary article of food, but a real pleasure, which I prefer, and believe to be more healthful than good wine or good beer. When water fails, man may suffer not only from cholera, but from all possible diseases. In places where cholera prevails the water may always be indicted, for the water supply is always a part of the locality, and the doctrine will frequently hold good, because the part may be mistaken for the whole. Where the influence of the water is held up to the exclusion of all other local factors error is liable to creep in. In England, where the drinking water theory is fully believed in, two like influences, in which every other local factor was excluded, were observed in the cholera epidemic of 1854. In one case, in a street in London which was supplied by two water companies, the Lambeth with pure water, and the Vauxhall with impure water, it was found that the cholera was practically limited to the houses supplied by the Vauxhall Company. I was so much impressed by this fact that I endeavoured to see whether the epidemic of 1854 in Munich could not be explained on a similar hypothesis. But my researches led me to a negative result. Without doubting the facts observed in London, I am of opinion that the impure water of the Vauxhall Company did not spread the germs of cholera, for the propagation of cholera was not effected by this means in Munich, but that the water increased either the personal predisposition to cholera or perhaps the local predisposition, since the water would be employed in the houses and about the soil. Later on, in 1866, Letheby doubted the accuracy of the drinking water theory, and proved that there had been considerable confusion; so that a house which was registered on the Lambeth Company really drew its water-supply from the main of the Vauxhall Company, and *vice versa*. The cholera epidemic of 1866 was essentially limited to East London. The East London Water Company supplied this district with water filtered from the river Lea. Letheby brought forward a series of facts to prove that we might with equal justice accuse the East London Gas Company, since the first case of cholera broke out at the gas factory."

His comments on the Broad Street pump outbreak continued as follows:

"A second instance in London was that with which the name of Dr. Snow is associated. Golden-square, a part of London with very deficient drainage, was the scene of a severe epidemic of cholera in 1854. The epidemic concentrated itself in Broad-street. There must have been some reason for this, and the reason must be discovered. Where Golden-square and Broad-street stood was formerly a place of burial for individuals dead of the plague. This pest-blast of a former century could walk from its grave in A.D. 1854 like the Ghost in Hamlet. But a narrower inspection proved that the old pest field and the new cholera field were not exactly coextensive. Now, however, another fact was brought to light, which led to the substitution of drinking water as the cause. In the middle of Broad-street there stood a pump of which the water was much esteemed on account of its freshness. At the end of August, whilst the cholera was raging, it was found out that many sufferers had drunk of the pump water, but the fact was not sufficiently decisive and so a pathological experiment was required. In Broad-street there was a percussion cap factory belonging to Mr. Eley. The persons of this establishment suffered from cholera, and many of them died. Mr. Eley remained well, but he did not live at the factory, though he went there daily and returned home to Hampstead after business, and there lived with his mother and a niece. His mother, who formerly lived in Broad-street, had a great liking for the water of the pump-well, which was shown in the fact that her son daily took home the water for his mother and niece. In Hampstead there had been no case of cholera until the mother and daughter fell ill and died of cholera without having any other communication with Broad-street than through the means mentioned. What more is wanted? Who can doubt any longer? An experiment on two human beings with a disease which animals are not susceptible to! A sad privilege! Never before had facts received a more frivolous interpretation. Suppose, for a moment, that Mr. Eley had gone to and from Hampstead to Broad-street without having taken the water to his mother and niece; and further, that they had become ill of the cholera without having drunk the pump water, would it have been imagined that the cholera had been carried by the son, who remained in good health? The contagionists would probably reply that Mr. Eley may have had the cholera in a mild form. The localists would say that a poison locally originated might be passed on by healthy people without giving signs of illness in them. In 1854, for example, a young lawyer went from Munich to Darmstadt, where his father resided. Up to that time the father had never lived out of Darmstadt, and Darmstadt was as free from cholera as Hamstead, and the distance from Munich was much greater than Hampstead from Broadstreet. The lawyer was as well in health as Mr. Eley had been, but the lawyer's father fell ill and died of cholera. There was no other factor in the case than the return of the son from Munich. Darmstadt enjoyed an immunity from cholera as great as that of Lyons, Versailles, Stuttgart, and many other large cities. In 1854 a workman went home from the Exhibition of Munich to Darmstadt, where he fell ill and died of cholera without the disease being spread to any other house, and no means for disinfection or isolation had been adopted. In 1866 Prussian troops were quartered in Darmstadt, and brought the cholera with them. About thirty of the soldiers became ill with cholera, and many of them succumbed; again, none of the inhabitants of Darmstadt had the disease. It must be admitted that Mrs. Eley might have been infected through the intercommunication of her son, just as the lawyer's father had been without the intervention of drinking water. The argument in favour of the drinking water theory rests on the fact that the cholera ceased when the supply of water was cut off; but no notice was taken of the great majority of cases in which the water springs were not closed and the supply of water not cut off, and yet the epidemics came to an end. Again, in Broadstreet the handle was not taken off till Sept. 8th. Now, an examination of the facts will show that the cholera was already subsiding. In Broad-street, on August 31st, there were 31 cases of cholera; on Sept. 1st, 131 cases; on the 2nd, 125; on the 3rd, 58; on the 4th, 52; on

the 5th, 26; on the 6th, 28; on the 7th, 22; and on the 8th, 14. Just as occurs in India and elsewhere, a violent epidemic generally subsides rapidly."

Pettenkofer's recognition that removal of the handle of the pump occurred after the epidemic was already subsiding is an observation shared by the many medical and public health students who have constructed an epidemic curve based on Snow's data (25) showing that the point when the pump handle came off was after the outbreak was on the wane.

Pettenkofer's views also differed from those of Koch on the spread of cholera although both were convinced that the cholera vibrio was the cause. Table 4 summarizes these differences based on Emmerich's monograph (15) and Hume's translation (1). As was true with his differences with Snow, Pettenkofer's fixation on the "Bodentheorie" to the exclusion of drinking water and other possible routes of transfer resulted in much loss of time and energy. Despite his introduction of the experimental method to hygiene and his interest in "shoe leather" epidemiology, he tended to select data favoring his own views—a not unnatural reaction. While William Budd shared with Snow the drinking water theory, others had at least some of Pettenkofer's skepticism. Farr gave it only qualified acceptance and even 20 years later such an authority as Hirsch still referred to contaminated water as a 'predisposing' cause of cholera (24). In retrospect it must be said that transmission of cholera through several mechanisms such as drinking water, personal contact with a patient, and transmission via a convalescent carrier or inapparent infection was not well appreciated during these years. Indeed, it was not until the 1893 cholera outbreak in Germany that Koch identified the carrier state and recognized its importance in transmission (27, 28). Even today there is still controversy over the major routes of spread of cholera. In some settings and for some strains transmission by water seems most important, whereas for other strains personal contact and carrier states are one more likely means of spread.

Despite his denial of the drinking water concept, Pettenkofer made significant contributions to the descriptive and historical aspects of the epidemiology of

TABLE 4
COMPARISON OF VIEWS OF PETTENKOFER AND KOCH ON CHOLERA^a

	Pettenkofer	Koch
1. Cause	Vibrio of Koch	Vibrio of Koch
2. Transmission	Not contagious directly from person to person	Person to person, including epidemics
3. Development of vibrio	In porous foul soil	Obligate human parasite
4. Spread	Depends on condition of the soil	Depends on personal fac- tors, especially cleanli- ness
5. Season	Marked seasonal trend	Not seasonal per se; just due to drinking more water, etc. in summer
6. Epidemics in times of drought	Due to sinking ground- water level	Low water level with less dilution of filth
7. Drinking water in epidemics	Plays no role	Explained on basis of drink- ing water
8. Prophylaxis	Change soil conditions	Detect 1st case, isolation, disinfection of stools, etc.

^a Adapted from Emmerich (15) and Hume (1).

cholera and of typhoid fever. He advocated and courageously defended the doctrine that more than just the organism was necessary to produce clinical disease. His arguments stimulated others to further inquiry. Unfortunately, his prodigious writing in support of his Boden theory, his opposition to Snow and to Koch, and his experimentum crucis have dominated his memory and observed his well-deserved place in the history of science. His important work in chemistry, in physiology, in nutrition, and in environmental health deserve wider attention. In particular his role in the establishment of chairs of hygiene in medical schools, his teaching on the subject, and his introduction of the experimental method to the field merit recognition.

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